TITLE:

Review of Sisal Production and Research in Tanzania

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CITATION:

KIMARO, Didas ...[et al]. Review of Sisal Production and Research in Tanzania. African Study Monographs 1994, 15(4): 227-242

ISSUE DATE:

1994-12

URL:

https://doi.org/10.14989/68124

RIGHT:

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REVIEW OF SISAL PRODUCTION AND RESEARCH IN TANZANIA

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ABSTRACT Sisal is an endemic tropical crop whose leaves provide the world's most important hard natural fibre used in the production of twines, ropes, sacks and carpets. This paper reviews the history of sisal in Tanzania, its production trends and current research on the crop. In the 1960's, the country produced large amounts of sisal and was the world's leading producer, contributing nearly 24% of the total world production; but from 1970 onwards, the production started to decline rapidly. Despite the decline, sisal is still considered important in the country's economy. Limited market prospects and unfavorable world market prices, inadequate research development and poor marketing arrangements are among the factors responsible for the decline in production. Moreover, research on soils and land suitability shows that continued sisal cultivation quickly depletes the soil nutrient reserves, thereby rendering the crop unable to attain high production levels. Some alternative land uses in Tanzania are suggested.

Key Words: Sisal; Production history; Production trends; Research; Tanzania.

INTRODUCTION

Sisal, *Agave sisalana*, is a monocotyledonous plant which grows best with rainfall of 1,000–1,250 mm per year but may grow with less. Excessive rainfall is harmful. In Tanzania, the sisal land use is basically a high input, large-scale monocropping system, dominating the hotter and drier areas below 900 m above sea level (Fig. 1). The sisal cultivating zones have land conditions for good crop growth and performance (Lock, 1962; Mande, 1980). The Korogwe-Muheza zone constitutes the center of the sisal industry in Tanzania. It is characterized by moderate and bimodal rainfall, hot climate and favourable soils for sisal cultivation. The second in importance is the Morogoro zone followed by the southern zone (Lindi-Mtwara). The northern zone is confined to the plains below the Kilimanjaro and Meru mountains. This zone has an average rainfall not exceeding 900 mm per annum.

Sisal provides the most important of the world's natural hard fibres used in making twines, ropes, sacks, and carpets. Centers of sisal production in East Africa include Tanzania, Kenya and Mozambique. Tanzania is presently the world's third largest producer after Brazil and Kenya. Although sisal was Tanzania's largest export during the early 1960's, bringing in over a quarter of the country's foreign ex-

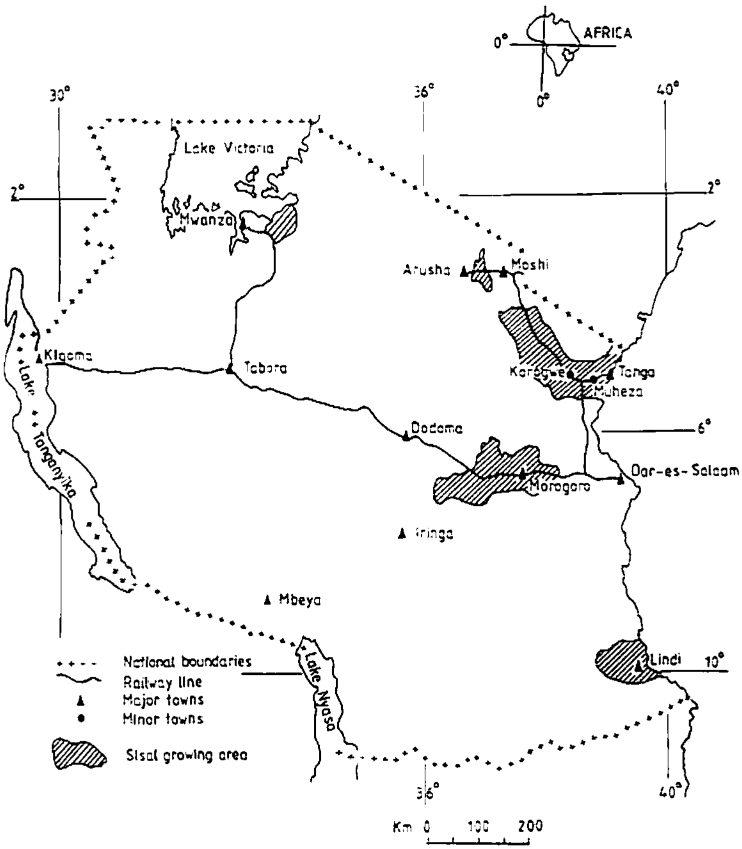

Fig. 1. Major sisal growing areas of Tanzania.

change earnings, its production and export have since then declined, while foreign exchange earnings from other crops, like coffee, cotton and cashewnuts, have surpassed those from sisal. Despite these developments, sisal is still important as it contributes to foreign exchange through exports of fibre and fibre-based products (see Table 1). The industry directly provides employment to between 40,000 and 50,000 people in the sisal estates. Moreover, sisal provides raw materials for the domestic sisal spinning and processing mills, which in turn provide additional employment. The introduction of sisal into Tanzania also stimulated other socio-economic developments, for example, the establishment of railway lines and roads, better planned housing, schools, clinics for sisal workers and other people living in and around the estates.

This paper describes historical background of sisal in Tanzania, its production trends, current research, and problems facing the sisal industry. In view of the unfavourable market prospects for the crop, the paper suggests some possible alternative crops in lieu of/or in combination with sisal.

Table 1. Tanzania sisal fibre and products export earnings.

Year	Sisal Fibre ('000 US$)	Sisal Products ('000 US$)	Total ('000 US$)
1985	5,525	5,500	11,025
1986	4,130	5,750	9,880
1987	4,532	7,150	11,682
1988	4,400	10,560	14,960
1989	4,408	10,360	14,768
1990	3,630	12,720	16,350
1991	1,300	10,890	12,190

Source: TSGA, 1992.

HISTORICAL BACKGROUND AND PRODUCTION TRENDS OF SISAL IN TANZANIA

Sisal was introduced into Tanganyika (now Tanzania) in 1893 by the German East Africa Company, which was at that time largely entrusted with the development of the country. The earliest sisal estates were situated near the sea on tidal estuaries for easy shipment of the sisal fibres and other products. In the early stages of sisal expansion, it was realized that transport facilities were the major bottleneck. Building transport facilities, especially railroads, was a very important task for colonial government, not only to develop net-works for political control in the rural area but to meet the demand of German enterpreneurs to exploit new markets for their products and tropical products (Munro, 1976). This led the German regime in Tanzania to build the first railway line which started in 1893 from Tanga Port. This Tanga-Moshi line reached the interior areas of Kilimanjaro and

Photo 1. Sisal plantation on hillside in Muheza area.

Arusha in 1911. The construction of the central line from Dar es Salaam to Kigoma started in 1905, and was completed shortly before 1914. With improved transport facilities, more sisal estates were established along the Tanga-Moshi line and the central Dar es Salaam-Kigoma line. Other estates were established along the southern Lindi line, connecting Lindi and Mtwara. Sisal was introduced as an alternative crop suitable for drier and hotter conditions, especially along the coastal areas of Tanzania. Other crops, such as coffee and tea, were considered more suited for the wet mountainous area, such as Kilimanjaro and Usambara. Sisal cultivation in other parts of the world i.e. the Bahamas and the Yucatan Peninsula of Mexico, were the basis of the supposition that sisal could be grown satisfactorily in some coastal areas of Tanzania. The German agronomist Hindorf, in 1893, ordered 1,000 bulbils of sisal from Florida to Hamburg, of which about 200 survived. These were repacked and sent to Tanga, but only 62 plants arrived in good enough condition to be planted at Kikongwe near the mouth of the Pangani river in Tanga Region. This was the foundation of the sisal industry in East Africa.

In the year 1900, the number of sisal plants in Tanzania had risen to over 500,000, and by the year 1902, it reached 1,600,000. About 2,000 ha were planted with sisal in the year 1904 (Lock, 1962). The first substantial export of sisal was in 1900, when about 7.5 tons of fibre were shipped to Hamburg. Figure 2 shows the trend of sisal fibre production and export from the early years to 1990. In the year 1905, the export of sisal rose to 1,400 tons and increased to about 7,000 tons in 1910. Sisal export continued to increase and tripled in 1913, just before the break out of the First World War. After the First World War, the annual sisal fibre production dropped to about 16,000 tons. Thereafter, with the improved sisal fibre price in the world market and the determination of the new British mandatory administration to revive the sisal industry, sisal production picked up again. In 1930, sisal fibre export had risen to about 50,000 tons. Despite many difficulties in sisal production in the early thirties, the production kept pace with demand, and the industry was able to plant new areas while maintaining old plantations.

The Second World War (1939–1945) and the Japanese invasion of the Philippines and Indonesia brought about a dramatic demand for hard fibres among the Allied countries. The sisal production in East Africa was promoted to meet such war demands. Production in Tanzania reached about 112,000 tons by 1945. The world price of sisal fibre rose dramatically in 1951, and accordingly, stimulated the cultivation of sisal throughout East Africa. The sisal cultivation area increased each year roughly by 60 percent. However, in 1952 and 1955, world sisal market price decreased slightly and caused a small decline in sisal production. Later on, prices improved again and the production of sisal in Tanzania reached 205,000 tons by 1960.

Up to the late 1960's, the production of sisal was substantially high (see Fig. 2); thereafter, a drastic decline in production took place. Sisal fibre production declined from 216,618 tons (about 24% of the world total) in 1967, to 30,151 tons 1986, a decline of 86%. In 1991, production rose slightly, to 36,000 tons (TSGA, 1992). Sisal cultivation area declined in similar proportions (see Fig. 3). The total area shrank from about 283,000 ha in 1967, to about 101,000 ha in 1984.

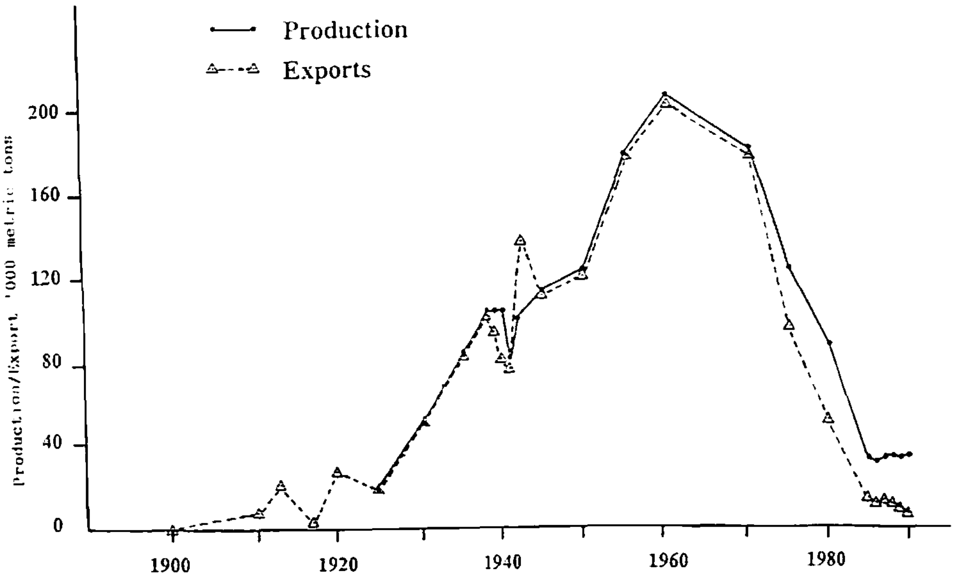

Fig. 2. Tanzania sisal fibre production and export trend (1900–1990) (Source: Lock, 1962; Guillebaud, 1966; Gweyer, 1971; TSGA, 1992).

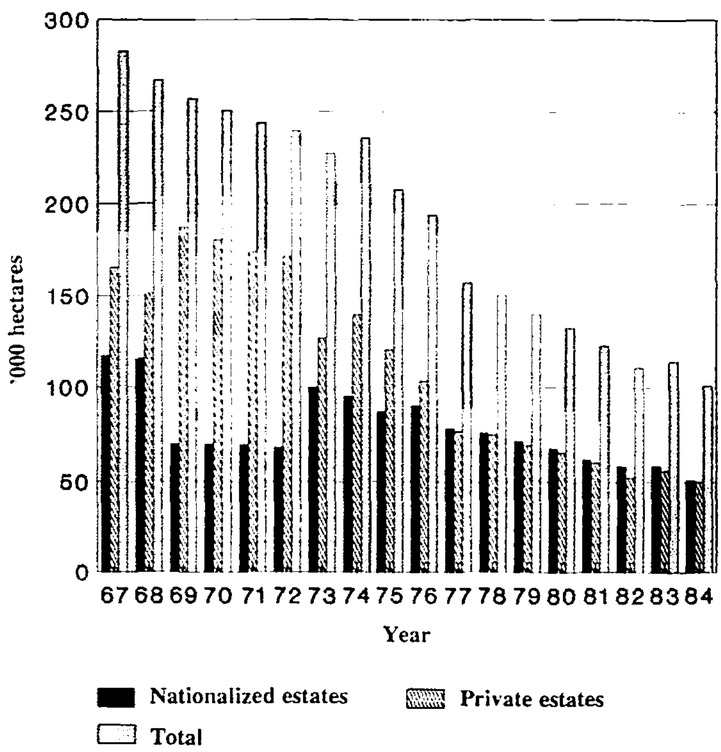

Fig. 3. Area planted to sisal (1967–1984) (Source: MALD, 1988).

PROBLEMS FACING THE SISAL INDUSTRY

The decline in sisal production was caused chiefly by the following factors:

1. Shrinking World Markets and the Sisal Price

The sisal fibre markets of Russia and Eastern Europe disappeared in a short period. Those in Western Europe, North America and Japan shrank drastically as the competition intensified between synthetic polypropylene and sisal fibre. Inevitably, the sisal fibre price went down drastically.

2. Nationalization of Sisal Estates

The nationalization of sisal estates after the independence of Tanzania in the late 1960's to early 1970's negatively affected the sisal production in that (a) there were very few trained local staff with the specialist skills required to manage the industry, (b) there was inadequate government structural policy to strengthen the industry in relation to production capacity, the price and marketing forces, (c) government economic hardships resulted in poor capital investment in the sisal industry, thereby frustrating farm operations, and the repair, maintenance, and purchase of new equipment and machines. Most nationalized estates, could not even afford to replant sisal, which is necessary every eight to ten years.

3. Inadequate Research and Development

Before the nationalization of the sisal estates, sisal research was organized and funded by the sisal growers themselves. After nationalization, the government turned the Sisal Research Institute into a general research centre, thereby diluting the emphasis on sisal. The situation was aggravated by the fact that the government, facing economic hardship, for a long time failed to support research in sisal agronomy, disease and pest control, and handling and processing technology.

4. Poor Marketing Arrangement

Until 1983, all Tanzania sisal was marketed through the Tanzania Sisal Authority's "single channel marketing" system (Ministry of Agriculture and Livestock Development — MALD, 1988) created in 1976. This system, contrary to expectations for improving marketing efficiency, proved to be very slow and unnecessarily bureaucratic. Private producers were dissatisfied and discouraged by this arrangement in their effort to increase production.

5. Shortage of Labor

For many years, a serious shortage of sisal cutters in both state and private-owned estates resulted in a large proportion of the crop being left unharvested (MALD, 1988). Many estates could fill only two-thirds of their labor force requirement. The shortage of labor is attributed to low rural minimum salary, poor housing, lack of incentives, inadequate social amenities and a shortage of essential commodities in almost all estates.

In view of some of the above problems, several attempts have been made by the government to restructure and improve the sisal industry. Among these attempts is the strengthening and development of sisal research in the areas of soils, general agronomy, breeding, pests and diseases. An account of sisal research in Tanzania follows.

CURRENT RESEARCH ON SISAL

The history of sisal research in Tanzania dates back to 1929, when fundamental research on the sisal plant started in Amani, Tanga Region, Tanzania (Lock, 1962). Research concentrated mainly on sisal plant selection and breeding with the emphasis on *Agave* species with the desirable characteristics of high leaf production and long fibres. In 1934, the sisal Experimental Station at Mlingano, Tanga Region, was instituted and became the main sisal research center in Tanzania. From this period, research also included studies on appropriate planting dates, and planting, spacing and harvesting methods. Plant nutrition, nutrition deficiencies, pests and diseases and the main soil types of the sisal growing zones were also important parts of the research program. Agricultural research was a major component of the activities related to sisal production in the early days before the massive nationalization of the sisal estates in the late 1960's.

Having gone through a period of serious decline in sisal production after the nationalization of sisal estates, there has been renewed effort to rehabilitate and improve the sisal industry, in particular through strengthened research. The following is an account of current sisal research undertaken in Tanzania.

1. Soils and Land Suitability for Sisal Cultivation

Commercial sisal cultivation at a relatively high input level requires environmental conditions that enable the sisal plant to produce high yields of good quality fibre in a relatively short period of time. Cultivating sisal, cycle after cycle, quickly depletes the soil nutrient reserves. This is a major problem in rehabilitating old estates in Tanzania. The optimal annual rainfall for sisal is reported to be around 1,250 mm (Acland, 1971; Purseglove, 1975), or but not more than 1,500 mm (Takashima, 1989) and should preferably be well distributed over the year. Sisal is, however, tolerant to drought.

Studies in Tanzania and other places indicate that sisal thrives well on a variety of soils, provided they are friable, freely draining, well-structured and adequately porous. Hybrid sisal is very sensitive to poor drainage and water-logging conditions. An effective soil depth of at least 100 cm is needed for good sisal rooting. Table 2 presents the optimal environmental requirements for sisal growth established on the basis of nutrients removed and fertilizer response data collected from field experiments carried out throughout the sisal growing areas in Tanzania (Nandra,

Table 2. Optimal environmental conditions determining land suitability for sisal cultivation in Tanzania.

	Optimal conditions
Yearly rainfall	1200–1500 mm per annum, fairly well-distributed, with maximum 3 consecutive dry months (with less than 70 mm of rain).
Physical soil conditions	Deep and very deep, well-drained friable soils without root restricting layer within 100 cm depth.
Natural soil fertility	Fertile soils, exchangeable calcium (Ca) more than 3.0 me/100 g soil, exchangeable potassium (K) more than 0.3 me/100 g soil with pH (H_2O) between 6 and 7 in topsoil, and aluminium saturation <30 percent in subsoil, total nitrogen more than 0.15 percent and C/N ratios around 10.
Erosion hazard	Topography, i.e. slopes less than 8%.

Source: Nandra, 1971, 1972.

1971, 1977). Continued sisal cultivation without fertilizer application or sisal waste return to the field rapidly depletes soil nutrient reserves.

More current studies on soil conditions of some sisal growing areas in Tanzania (Van Kekem & Kimaro, 1986; Kimaro & Van Kekem, 1987; Kips et al., 1989; Mbogoni et al., 1989; Ngailo et al., 1990) clearly indicate that repeated sisal cropping greatly reduce soil chemical fertility. The extent of the decline in soil chemical fertility is substantiated by the soil chemical data of selected profiles given in Tables 3 to 5. Comparison of the soil chemical analysis from corresponding virgin soil profiles (Tables 6 to 8) clearly shows a decline in soil fertility when continuous cropping is practiced.

Soils currently under sisal cultivation show pH values of about 5, too low for optimum sisal production. Analytical data also show calcium levels in the soils much lower than those of corresponding virgin soils, and, in some cases, below the critical optimum level required for sustained sisal production. Sisal is known to require calcium, removing large quantities of this nutrient from the soil. The potassium content of these soils is also very low (less than 0.1 me/100 g soil). Nitrogen, organic matter and magnesium are also important in sisal nutrition. Whereas

Table 3. Analytical data of a soil profile on sandstone from undulating coastal plain in Tanga Dstrict, Tanzania.

Parameter	Sampling Depth (cm)			
	0–20	25–40	50–70	90–110
pH (H_2O)	5.5	5.2	5.0	5.0
Organic carbon %	0.6	0.4	0.2	0.2
Total nitrogen	0.05	0.03	n.d.	n.d.
Available phosphorus mg/kg	4.6	1.9	1.9	2.0
Exchangeable Ca me/100 g soil	0.7	0.7	0.5	0.4
Exchangeable Mg 〃	0.6	0.4	0.3	0.3
Exchangeable K 〃	0.1	tr	0.1	tr
Exchangeable Na 〃	0.1	tr	tr	tr
Base saturation %	45	52	30	40

n.d.: not determined, tr: trace.
Source: Van Kekem & Kimaro, 1986.

Table 4. Analytical data of a soils profile on limestone from nearly flat coastal plain in Lindi District, Tanzania.

Parameter	Sampling Depth (cm)			
	10–20	20–35	50–70	90–110
pH (H_2O)	5.0	4.4	4.3	4.5
Organic carbon %	1.5	0.5	0.2	0.2
Total nitrogen %	0.08	0.07	n.d.	n.d.
Available phosphorus mg/kg	5.0	3.0	3.0	2.0
Exchangeable Ca me/100 g soil	5.1	1.9	1.0	1.0
Exchangeable Mg me/100 g soil	2.3	1.3	1.0	1.0
Exchangeable K me/100 g soil	0.1	0.1	0.1	tr
Exchangeable Na me/100 g soil	0.1	0.1	0.2	0.2
Base saturation %	50	31	29	26

n.d.: not determined, tr: trace.
Source: Kimaro & Van Kekem, 1987.

Table 5. Analytical data of a soil profile on gneissic rocks from dissected peneplain in Muheza District, Tanzania.

Parameter	Sampling Depth (cm)			
	10–12	12–25	25–50	50–83
pH (H_2O)	5.2	5.1	5.2	5.4
Organic carbon %	2.3	1.1	0.8	0.5
Total nitrogen %	0.16	0.09	0.08	0.05
Available phosphorus mg/kg	1.0	1.0	1.0	1.0
Exchangeable Ca me/100 g soil	2.1	1.6	2.2	1.5
Exchangeable Mg me/100 g soil	0.7	0.4	0.7	1.0
Exchangeable K me/100 g soil	0.07	0.03	0.2	0.01
Exchangeable Na me/100 g soil	0.11	0.08	0.05	0.04
Base saturation %	44	29	31	28

Source: Mbogoni et al., 1989.

organic matter content does not seem to be a problem, particularly for surface soils, nitrogen and magnesium are limiting. Base saturation, a simple index of soil fertility, is, in most cases, much lower than 50%. The overall impression from the analytical data is that soil fertility is a major limiting factor to sustained sisal cultivation. With the fertility levels observed (Tables 3 to 5), the soils are unsuitable or only marginaly suitable for commercial or large-scale sisal cultivation in Tanzania.

Table 6. Analytical data of a virgin soil profile on sandstone from undulating coastal plain in Tanga District, Tanzania.

Parameter	Sampling Depth (cm)			
	0–10	10–20	50–70	100–120
pH (H_2O)	6.8	6.5	6.7	6.7
Organic carbon %	0.80	0.50	0.40	0.10
Total nitrogen %	0.08	0.04	0.03	0.03
Available phosphorus mg/kg	3.5	2.1	2.1	2.1
Exchangeable Ca me/100 g soil	3.1	1.30	1.00	0.9
Exchangeable Mg me/100 g soil	1.30	0.90	0.70	0.30
Exchangeable K me/100 g soil	0.40	0.20	0.20	0.20
Exchangeable Na me/100 g soil	0.10	0.10	tr	tr
Base saturation %	10	96	73	70

tr: trace.
Source: Van Kekem & Kimaro, 1986.

Table 7. Analytical data on a virgin soil profile on limestone from nearly flat coastal plain in Lindi District, Tanzania.

Parameter	Sampling Depth (cm)			
	0–15	20–35	50–70	100–120
pH (H_2O)	6.7	6.3	6.6	6.5
Organic carbon %	2.6	1.4	0.5	0.4
Total nitrogen %	0.20	0.09	n.d.	n.d.
Available phosphorus mg/kg	3	3	3	2
Exchangeable Ca me/100 g soil	12.9	8.9	7.9	7.3
Exchangeable Mg me/100 g soil	6.6	4.1	3.4	3.8
Exchangeable K me/100 g soil	0.9	0.9	0.8	0.8
Exchangeable Na me/100 g soil	0.2	0.1	0.4	0.3
Base saturation %	92	81	87	80

n.d.: not determined.
Source: Kimaro & Van Kekem, 1987.

2. Sisal Breeding

Amongst sisal varieties, *Agave sisalana* is the most preferred. It has many valuable attributes, notably, hardness with adaptability, and the capacity to sustain high yields. *Agave sisalana* is known to adapt to different soils and a fairly wide range of climatic conditions, besides being resistant to pests and diseases.

Table 8. Analytical data on a virgin soil profile on gneissic rocks from dissected peneplain in Muheza District, Tanzania.

Parameter	Sampling Depth (cm)				
	0–10	10–20	20–30	30–50	50–100
pH (H_2O)	6.6	7.0	5.7	5.2	5.1
Organic carbon %	1.3	0.86	0.14	n.d.	n.d.
Total nitrogen %	0.33	0.19	0.07	0.05	0.04
Available phosphorus mg/kg	90	22	10	10	n.d.
Exchangeable Ca me/100 g soil	10.1	5.3	0.34	0.07	0.06
Exchangeable Mg me/100 g soil	6.3	4.7	1.9	0.6	1.0
Exchangeable K me/100 g soil	0.74	0.67	0.75	0.43	0.43
Exchangeable Na me/100 g soil	0.10	0.08	0.09	0.08	0.11
Base saturation %	85	88	50	27	40

n.d.: not determined.
Source: Lock, 1962.

Given these qualities of *Agave sisalana*, efforts were made to obtain even more superior forms of *Agave* through breeding techniques. The first breeding work in Tanzania for longer fibre *Agaves* were made in 1931. Five principle cultivated species were used, i.e., *A. sisalana, A. fourcroydes, A. cantala, A. angustifolia* and *A. amaniensis*. Several breeding methods were used, but specific hybridization proved much more useful for the breeding of more productive types. The cross-pollination of *A. angustifolia* with *A. amaniensis* turned out the best. Through back-crossing and self-pollination a sisal variety called Hybrid 11648 was produced in the 1940's and 1950's, which was superior to the normal cultivated sisal variety of *A. sisalana* (Lock, 1962). With low planting density, it produced fewer number of leaves but with a higher content of fibre. It was also easier to cut for harvesting.

At present, most sisal farms in Tanzania grow Hybrid 11648 and *A. sisalana*. Current research remains focused on evolving better cultivars than the two currently in use. Emphasis is put on specific hybridization and clonal selection, including selfing and back crossing, variety evaluation, mutation breeding, *Agave* species and hybrid collection (Ministry of Agriculture Livestock Development and Cooperatives — MALDC, 1990). The objective of the inter-specific hybridization research program is to try to incorporate in the sisal hybrids the characteristics of disease resistance, high yields with good fibre quality, and adaptability to different agro-ecological zones. The objective of mutation breeding is to induce spine-free leaf margins and high leaf number in *Agave sisalana*, and disease resistance, particularly against "Korogwe leaf spot," zebra leaf rot and bole rot diseases, which commonly occur in Hybrid 11648. Different *Agave* species and hybrids are maintained at the sisal research station to serve as a germplasm for future sisal breeding. The collection is expected to meet the future needs related to a variety of problems in the sisal industry, by providing parents for breeding alternative cultivars.

3. Pests and Diseases

Sisal is generally tolerant to environmental stress, such as drought, poor soils, pests and diseases. However, some pests and diseases pose serious problems. The sisal research program in Tanzania is mainly focused on insect pest surveys, bole trapping insecticide trials and disease screening. The most serious insect pest is the sisal weevil (*Scyphophorus intenstitialis*) (MALDC, 1990). The larvae and adults cause considerable losses in nurseries and young sisal fields, particularly during and immediately after the wet season. The pest may cause up to 60% damage or more, if control measures are not taken.

The goal of current research is to screen insecticide chemicals for the control of the sisal weevil. Such chemicals include Decis (2.5 EC), Hostathion (40 EC), Curacron (EC), Carbicron (EC) and Kynadrin (18 EC). Sisal, particularly the *Agave* hybrids, are susceptible to three main diseases, namely zebra leaf rot, bole rot caused by the fungi *Phytophthora spp.* (Wienk, 1968 a & b; Peregrine, 1969), and *Aspergillus niger* (Wallace & Dieckmahns, 1952), and Korogwe leaf spot (K.L.S.), recently observed to be associated with a virus (Swai, L., pers. comm.). Deficiencies of potassium and calcium, widespread in sisal estates, accentuate these infections.

4. Agronomic Characteristics of Hybrid Sisal and *Agave sisalana*

The overall yield of sisal depends on the number of leaves produced before flowering, or "poling" (Gwyer, 1971). The rate of yield, more important economically, depends on both the rate of leaf production and the rate at which the leaves increase in size. It has been observed, for example, that Hybrid 11648, bred at the Sisal Research Station, Mlingano, not only produces many more leaves than *Agave sisalana* but its rate of leaf production is greater. Table 9 compares the growth performance of the two varieties. It can be said that the hybrid outperformes *Agave sisalana* both in overall yield and rate of leaf production. Although the difference in rate of yield is still great, it is less marked because the rate of leaf growth is slower for the hybrid, and, hence, the cycle is longer. The hybrid sisal has the disad-

Table 9. Relative performance of Hybrid 11648 and *Agave sisalana*.

Performance criteria	Hybrid 11648	*Agave sisalana*
Plants per ha	5,000	4,000
Number of leaves grown per plant per cycle	648	205
Number of leaves grown per plant per month	5.9	2.8
Average leaf weight (grams)	520	548
Total fibre yield (tons per ha)	62.8	22.6
Fibre yield per year (ton per ha)	6.8	3.7
Length of cycle from planting to poling (months)	110	74

Source: Hopkinson & Wienk, 1966.

vantage that it has low resistance to *Phytophthora* attack and its propensity to flower early at high altitudes, which limits its range of commercial cultivation to free draining soils at less than 900 m above sea level.

Although most sisal farms in Tanzania grow Hybrid 11648, the agronomic and ecological recommendations normally applied are those based on experiences with *Agave sisalana*. In order to improve yields of hybrid sisal, several attempts have been made in agronomy and management research. Such agronomic research includes trials on spacing, the time of transplanting bulbils from the nurseries, investigation on the rates, time and methods of lime application, and weed control through intercropping of annual food crops, cover crops and mechanical weeding. As indicated earlier, sisal is calcium-demanding and removes a lot of this nutrient from the soil. Several studies on sisal have shown that applying lime at the rate of 5 tons per ha is optimal for various soils in most sisal growing areas. However, from recent observations (MALDC, 1990), it is indicated that, with lime application, even at the rate of 5 tons per ha, calcium deficiency symptoms may still occur. Sisal land management through fertilizer application is of paramount importance. Observations have indicated that applying nitrogen, potash and phosphate fertilizers will improve sisal yields (MALDC, 1990). In Tanzania, Calcium Ammonium Nitrate (CAN) is recommended as a nitrogen fertilizer with a low soil pH-decreasing effect in most soils in the sisal growing areas. It is further recommended that nitrogen fertilizer be applied in conjunction with potassium fertilizer in order to avoid banding disease. In most cases, sulphate of potash (muriate of potash) is recommended. For the acid soils, rock phosphate is recommended as a source of phosphorus. Cultivation of a grass legume fallow after each cycle of hybrid sisal restores the natural fertility of the soils and reduces fertilizer requirements of the next sisal crop.

ALTERNATIVE CROPS AND LAND USES FOR SISAL

In the past and especially before 1967, the majority of sisal estates in Tanzania were engaged only in producing sisal (Mande, 1980; TSGA, 1992). In view of the problems facing the sisal industry, i.e. the decline in demand for sisal and the low production trends, it is plausible to think of alternative crops and land uses. Mande (1980) recommended sunflower as a potential alternative crop, based on its economic viability. More recent land suitability studies of the existing sisal lands recommend crops for which further testing may be required (Kimaro & Van Kekem, 1987; Kips et al., 1989; Mbogoni et al., 1989; Ngailo et al., 1990). These are:

(1) Citrus *(Citrus sinensis, C. limon, C. paradisi, C. aurantifolia, C. grandis, C. reticulata)*

In most of the sisal growing zones, citrus is an important commercial crop. It is an attractive cash source, especially to small-scale farmers. Generally, citrus trees can withstand fairly long dry periods because of the waxy character of the citrus leaf, keeping transpiration low. For a good citrus yield, a yearly rainfall of 1,000 to 1,500 mm is considered optimal. Citrus requires well-aerated and well-drained soils, but does not require very fertile soils and is known to do relatively well on poor soils. Moreover, most citrus are tolerant to high levels of exchangeable aluminium in the soil. Given these conditions, citrus can be recommended as an alternative crop to sisal, especially in the Muheza-Korogwe zone.

(2) Pineapple *(Ananas comosus)*

Pineapple is a hardy plant that can withstand long dry spells, as it has special storage cells in the fibrous leaves. Pineapple requires fairly evenly distributed rainfall, and an optimum annual rainfall between 1,000 and 1,500 mm. Pineapple also requires a reasonable soil fertility level, and prefers friable and easily rootable soils. Acidic soils with pH levels between 5 and 6 are considered best for pineapple production. Most sisal growing areas could reasonably be considered for pineapple production.

(3) Cashew *(Anacardium oxidentale)*

Cashew is a tree crop very well-adapted to most environmental conditions suitable for sisal. The optimal annual rainfall required for growing cashew is 750–1,000 mm. A prolonged dry season of 6 months with less than 40 mm rain/month is needed for flowering and proper ripening of the fruit (Acland, 1971). Cashew requires very deep, well-drained, porous soils with a good fertility status. The ecological conditions in the southern zone are favourable for successful cultivation of cashew as an alternative crop to sisal.

Other alternative land uses which could be considered include animal husbandry on pure pasture land as a replacement or suppliment to sisal. Maize and beans grown together with or after sisal, such grasses as elephant grass (*Pennisetum purpureum*), Rhodes grass (*Chloris gayana*), Teff grass (*Eragrostis tef*), and tropical kudzu (*Pueraria phaseoloides*) are recommended for making hay and direct grazing.

CONCLUSION

Sisal production in Tanzania has steadly declined, particularly from the 1970's. However, sisal remains an important crop as it contributes substantially to the country's economy. There is, therefore, a clear need for urgent government support, including financial help and an improved marketing system to assist sisal growers improve and maintain their production levels.

The paper suggests some alternative land uses. Further research is, however, needed to better define these land uses. Specialists in horticulture, agricultural economists, sisal agronomists and soil scientists have to work together to come up with sound recommendations on agronomic and economic implications of cultivating the suggested crops in the existing sisal cropping system. In addition to soils, agronomic, and economic research, we call for further studies to establish appropriate plant configurations, population mixtures, plant species, and rotations.

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——— Accepted *January 20, 1994*

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